

Claims

- 1 1. A method for selecting an object in a three-dimensional modeling environment, the
2 method comprising the steps of:
3 generating a three-dimensional modeling environment containing one or more virtual
4 objects and a three-dimensional cursor;
5 determining a first three-dimensional cursor position in said three dimensional
6 modeling environment, said three-dimensional cursor position corresponding to a
7 position of an input device having at least three degrees of freedom;
8 representing a first view of at least one of said one or more virtual objects in a first
9 two-dimensional display space;
10 representing said three-dimensional cursor position in said two-dimensional display
11 space; and
12 selecting one of said virtual objects based on a positional correspondence of said
13 object and said cursor in said two-dimensional display space.
- 1 2. The method of claim 1, wherein said input device has at least six degrees of freedom.
- 1 3. The method of claim 1, wherein said input device has exactly six degrees of freedom.
- 1 4. The method of claim 1, wherein said virtual object comprises a selected one of a point, a
2 straight line segment, a curvilinear segment, a spline, a two-dimensional representation, and a
3 three dimensional representation.
- 1 5. The method of claim 1, further comprising the step of editing said selected virtual object.
- 1 6. The method of claim 5, wherein editing said selected virtual object comprises a selected
2 one of coloring said object, modifying said object, combining said object with another virtual
3 object, grouping said object with another object, deleting said object, and renaming said object.

1 7. The method of claim 5, wherein editing said selected virtual object comprises sculpting
2 said selected virtual object.

1 8. The method of claim 1, further comprising the step of performing a file function
2 involving said selected virtual object.

1 9. The method of claim 8, wherein performing a file function comprises saving said object
2 to a file.

1 10. The method of claim 1, wherein representing a first view of at least one of said one or
2 more virtual objects comprises representing said one or more virtual objects in a selected one of a
3 perspective view and an orthogonal view.

1 11. The method of claim 1, further comprising the steps of:
2 selecting a local origin point on said selected virtual object; and
3 defining a mathematical transformation in said three-dimensional modeling
4 environment, said mathematical transformation representative of a difference in
5 location of said local origin point and said three-dimensional cursor position.

1 12. The method of claim 11, wherein said local origin point is an arbitrary point on said
2 object.

1 13. The method of claim 11, wherein defining said mathematical transformation comprises
2 defining a vector having a component directed orthogonal to said two-dimensional display space.

1 14. The method of claim 11, wherein defining said mathematical transformation comprises
2 defining a mathematical transformation having at least one of a three-dimensional translational
3 vector, a rotation about said local origin point, and a rotation about said three-dimensional cursor
4 position.

- 1 15. The method of claim 11, further comprising the steps of:
2 applying said transformation; and
3 manipulating said virtual object, said manipulation of said virtual object
4 corresponding to a manipulation of said input device by the user.
- 1 16. The method of claim 11, further comprising the step of manipulating said virtual object,
2 said manipulation of said virtual object corresponding to a manipulation of said input device by
3 the user combined with an application of said transformation.
- 1 17. The method of claim 15, wherein said manipulation of said input device comprises at
2 least one of a translational degree of freedom and a rotational degree of freedom.
- 1 18. The method of claim 17, wherein said manipulation of said input device comprises a
2 simultaneous manipulation of two or more independent degrees of freedom.
- 1 19. The method of claim 17, wherein said manipulation of said input device comprises a
2 simultaneous manipulation of three or more independent degrees of freedom.
- 1 20. The method of claim 17, wherein said manipulation of said input device comprises a
2 simultaneous manipulation of six or more independent degrees of freedom.
- 1 21. The method of claim 15, further comprising the step of relocating said three-dimensional
2 cursor to the location of the local origin point by application of the mathematical transformation.
- 1 22. The method of claim 21, wherein the relocating step is performed only during a duration
2 of the manipulation.
- 1 23. The method of claim 22, further comprising the step of providing a visual aid to help a
2 user select and manipulate said virtual object.

1 24. The method of claim 23, wherein providing said visual aid comprises providing a user-
2 activated constraint limiting a point to a locus aligned to an axis of said three-dimensional
3 modeling environment.

1 25. The method of claim 15, further comprising the step of moving said three dimensional
2 cursor to a position the cursor would have if manipulation of said input device by a user had been
3 applied directly to said three dimensional cursor.

1 26. The method of claim 25, wherein the moving step is performed upon a command issued
2 by the user.

1 27. The method of claim 26, wherein said command is a release of said selected virtual
2 object.

1 28. The method of claim 15, further comprising the step of providing a visual aid to help a
2 user select and manipulate said virtual object.

1 29. The method of claim 28, wherein providing said visual aid comprises providing a user-
2 activated constraint limiting a point to a locus aligned to an axis of said three-dimensional
3 modeling environment.

1 30. The method of claim 28, wherein providing said visual aid comprises providing a
2 context-specific visual aid consistent with user-defined geometrical limitations.

1 31. The method of claim 28, wherein providing said visual aid comprises representing a
2 second view of at least one of said one or more virtual objects in a second two-dimensional
3 display space, said first two-dimensional display space and said second two-dimensional display
4 space corresponding to different planes of said three-dimensional modeling environment.

1 32. The method of claim 31, wherein representing said second view comprises representing
2 said second view on said second two-dimensional display space whose plane is orthogonal to a
3 plane of said first two-dimensional display space.

1 33. The method of any of claims 1, 5, 8, 11, 15, 16, 21, 23, 25, or 28, wherein said input
2 device comprises a haptic device.

1 34. The method of claim 33, wherein said haptic device comprises a haptic device providing
2 force feedback to actuators operating in at least three degrees of freedom.

1 35. The method of claim 34, further comprising the step of providing a haptic aid to help a
2 user select and manipulate said virtual object.

1 36. The method of claim 35, wherein said haptic aid comprises provision of dynamic friction
2 force during said positional correspondence of said object and said cursor in said two-
3 dimensional display space.

1 37. The method of claim 35, wherein, during an activation of said user-activated visual
2 constraint limiting a point to a locus aligned to an axis of said three-dimensional modeling
3 environment, said haptic aid comprises a haptic constraint limiting generally motion of the three-
4 dimensional cursor to directions aligned to an axis of said three dimensional environment within
5 a region of radius R about an identified point.

1 38. The method of claim 37, further comprising the step of contemporaneously displaying a
2 visual aid component that indicates an axial location of said cursor along an axis.

1 39. The method of claim 35, wherein, during an activation of said user-activated visual
2 constraint limiting a point to a selected line, said haptic aid comprises a haptic constraint limiting
3 motion of the three-dimensional cursor to said line.

1 40. The method of claim 39, further comprising the step of contemporaneously displaying a
2 visual aid component that indicates location of an axial location of said cursor along an axis.

1 41. The method of claim 35, wherein, during an activation of said user-activated visual
2 constraint limiting a point to a selected plane, said haptic aid comprises a haptic constraint
3 limiting motion of the three-dimensional cursor to said plane.

1 42. The method of claim 41, further comprising the step of contemporaneously displaying a
2 visual aid component that indicates location of said plane.

1 43. An apparatus that permits a user to select an object in a three-dimensional modeling
2 environment, comprising:
3 a computer that supports a three-dimensional modeling environment application;
4 an input device that provides user input to said computer, said input device having at
5 least three degrees of freedom;
6 a modeling module that, when operating, generates said three-dimensional modeling
7 environment using said computer, said three-dimensional modeling environment
8 adapted to model one or more virtual objects and to employ a three-dimensional
9 cursor; and
10 a selection module responsive to user commands that, when operating, selects one of
11 said virtual objects based on a two-dimensional positional correspondence of said
12 object and said cursor.

1 44. The apparatus of claim 43, further comprising a display device that provides a two-
2 dimensional display space for presenting to the user representations of said virtual object and
3 said three-dimensional cursor in said modeling environment.

1 45. The apparatus of claim 44, further comprising a rendering module that, when operating,
2 renders on said display device a view of said virtual object in a selected one of a perspective view
3 and an orthogonal view.

1 46. The apparatus of claim 43, wherein said input device has at least six degrees of freedom.

1 47. The apparatus of claim 43, wherein said input device has exactly six degrees of freedom.

1 48. The apparatus of claim 43, wherein said virtual object comprises a selected one of a
2 point, a straight line segment, a curvilinear segment, a spline, a two-dimensional representation,
3 and a three dimensional representation.

1 49. The apparatus of claim 43, further comprising an editing module that, when operating,
2 edits said selected virtual object in response to user input.

1 50. The apparatus of claim 49, wherein said editing module comprises a selected one of a
2 module that sculpts said object, a module that colors said object, a module that modifies said
3 object, a module that combines said object with another virtual object, a module that groups said
4 object with another object, a module that deletes said object, a module that renames said object,
5 and a module that performs a file function involving said object.

1 51. The apparatus of claim 43, further comprising:
2 a cursor tracking module that, when operating, determines a position of said three-
3 dimensional cursor in said three dimensional modeling environment, said position
4 of said cursor corresponding to a position of said input device;
5 an object tracking module that, when operating, tracks a local origin point on said
6 selected virtual object; and
7 a transformation module that, when operating, defines a mathematical transformation
8 in said three-dimensional modeling environment, said mathematical transformation
9 representative of a difference in location of said local origin point and said three-
10 dimensional cursor position at a time the user selects said virtual object.

1 52. The apparatus of claim 51, wherein said transformation module defines said mathematical
2 transformation in terms of at least one of a three-dimensional translational vector, a rotation
3 about said local origin point, and a rotation about said three-dimensional cursor position.

1 53. The apparatus of claim 51, further comprising:
2 an object manipulation module that, when operating, manipulates said virtual object,
3 said manipulation of said virtual object corresponding to a manipulation of said
4 input device by the user combined with an application of said transformation.

1 54. The apparatus of claim 53, wherein said object manipulation module represents said
2 manipulation of said input device using at least one of a translational degree of freedom and a
3 rotational degree of freedom.

1 55. The apparatus of claim 53, wherein said object manipulation module is adapted to
2 manipulate at least two independent degrees of freedom simultaneously.

1 56. The apparatus of claim 53, wherein said object manipulation module is adapted to
2 manipulate at least three independent degrees of freedom simultaneously.

1 57. The apparatus of claim 53, wherein said object manipulation module is adapted to
2 manipulate at least six independent degrees of freedom simultaneously.

1 58. The apparatus of claim 53, further comprising a relocation module that, when operating,
2 relocates said three-dimensional cursor to said location of said local origin point by application
3 of said mathematical transformation.

1 59. The apparatus of claim 58, wherein said relocation module is operative only during
2 duration of the manipulation.

1 60. The apparatus of claim 59, further comprising a visual aid module that, when operating,
2 provides a visual aid to help the user select and manipulate said virtual object.

1 61. The apparatus of claim 60, wherein said visual aid module is responsive to a user
2 command, said visual aid module constraining a display of a point manipulated by a user to a
3 locus aligned to an axis of said three-dimensional modeling environment.

1 62. The apparatus of claim 51, further comprising a cursor repositioning module that, when
2 operating, moves said three dimensional cursor to a position the cursor would have if said
3 manipulation of said input device by the user had been applied directly to said three dimensional
4 cursor.

1 63. The apparatus of claim 62, wherein said cursor repositioning module operates in response
2 to a command issued by the user.

1 64. The apparatus of claim 63, wherein said command is a release of said selected virtual
2 object.

1 65. The apparatus of claim 54, further comprising a visual aid module that, when operating,
2 provides a visual aid to help the user select and manipulate said virtual object.

1 66. The apparatus of claim 65, wherein said visual aid module is responsive to a user
2 command, said visual aid module constraining a display of a point manipulated by the user to a
3 locus aligned to an axis of said three-dimensional modeling environment.

1 67. The apparatus of claim 65, wherein said visual aid module is responsive to a user
2 command, said visual aid module constraining a display of a point manipulated by the user to a
3 locus consistent with user-defined geometrical limitations.

1 68. The apparatus of claim 65, wherein said visual aid module represents a second view of at
2 least one of said one or more virtual objects in a second two-dimensional display space, said first
3 two-dimensional display space and said second two-dimensional display space corresponding to
4 different planes of said three-dimensional modeling environment.

1 69. The apparatus of claim 68, wherein said visual aid module represents said second view on
2 said second two-dimensional display space whose plane is orthogonal to a plane of said first two-
3 dimensional display space.

1 70. The apparatus of any of claims 43, 44, 45, 49, 51, 53, 58, 60, 62, or 65, wherein said
2 input device comprises a haptic device.

1 71. The apparatus of claim 70, wherein said haptic device comprises a haptic device having
2 force feedback actuators operating in at least three degrees of freedom to apply force to the user.

1 72. The apparatus of claim 71, further comprising a haptic aid module to help the user select
2 and manipulate said virtual object.

1 73. The apparatus of claim 72, wherein said haptic aid module computes a dynamic friction
2 force to be applied to the user by said haptic device during a positional correspondence of said
3 object and said cursor in two dimensions of said three-dimensional modeling environment.

1 74. The apparatus of claim 72, wherein, during an activation of said user-activated visual
2 constraint limiting a point to a locus aligned to an axis of said three-dimensional modeling
3 environment, said haptic aid module activates at least one of said force feedback actuators to
4 provide haptic force to the user upon deviation of said point from said locus.

1 75. The apparatus of claim 74, wherein said visual aid module is additionally adapted to
2 display a visual aid component that indicates a location of said cursor along an axis.

1 76. The apparatus of claim 72, wherein, during an activation of said user-activated visual
2 constraint limiting a point to a selected line, said haptic aid module activates at least one of said
3 force feedback actuators to provide haptic force to the user upon deviation of said point from said
4 line.

1 77. The apparatus of claim 76, wherein said visual aid module is additionally adapted to
2 display a visual aid component that indicates a location of said cursor along a line.

1 78. The apparatus of claim 72, wherein, during an activation of said user-activated visual
2 constraint limiting a point to a selected plane, said haptic aid module activates at least one of said
3 force feedback actuators to provide haptic force to the user upon deviation of said point from said
4 plane.

1 79. The apparatus of claim 78, wherein said visual aid module is additionally adapted to
2 display a visual aid component that indicates a location of said cursor on a plane.